DOCUMENT RESUME

ED 351 186 SE 052 403

AUTHOR	Geddis, Arthur N.
TITLE	What To Do about "Misconceptions"--A Paradigm Shift.
PUB DATE	Apr 91
NOTE	24p.; Paper presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, April, 1991).
PUB TYPE	Information Analyses (070) -- Reports - Descriptive (141) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Concept Formation; *Constructivism (Learning); Learning Theories; *Misconceptions; Physics; *Science Education; Science Instruction; *Scientific Concepts; Secondary Education
IDENTIFIERS	Wave Theory

ABSTRACT

This use of the term "student's misconceptions" reflects a knowledge transmission view of teaching rather than a constructivist view. Among science educators there has been an undue emphasis on changing student views into views accepted by the scientific community. This overemphasis mirrors the preoccupation with transmitting the "right answer" found in many classrooms and deflects attention away from the origin and justification of scientific views. There are three central factors in helping students move from their common sense methodology to a scientific one. First, students need to be skeptical about what seems evident. Second, they need opportunities to imagine alternative possibilities. And third, they need practice in employing some of the criteria used in science to validate their alternative ideas. A case study of the teaching of waves to high school students in an introductory physics course demonstrates how the origin and justification of the scientific concept of a wave can be focused within a constructivist perspective of science teaching. (Contains 28 references.) (PR)

What to Do About Science "Misconceptions"--

A Paradigm Shift

Arthur N. Geddis

Faculty of Education

University of Western Ontario

London, Canada

Running Head: A Paradigm Shift

Paper presented at the annual meeting of the
American Educational Research Association
Chicago, Illinois, April 1991

What to Do About Science "Misconceptions"--
A Paradigm Shift

Introduction

The last two decades have witnessed phenomenal growth in research into the views students hold of scientific phenomena prior to instruction (Gilbert & Watts, 1983; Eylon & Linn, 1988). These studies reveal (i) that students' views are often very different from accepted scientific views, and (ii) that these views can be very difficult to change. For both teachers and researchers, this raises the question, "What are we to do about students' scientific misconceptions?" Researchers appear to have assumed that students need to adopt accepted scientific views. They've then conceptualized learning in terms of conceptual change, and proceeded to investigate how instruction can best bring about conceptual change (e.g., Hewson, 1985; Nussbaum & Novick, 1982; Rowell, Dawson & Lyndon, 1990). This approach, however, has not met with overwhelming success. Recent studies have confirmed that even when teachers teach for conceptual change, many students tenaciously hold on to their own views (e.g., Dreyfus, Jungwirth & Eliovitch, 1990; Linn, 1983). Of even greater concern is the documentation of cases where students consciously adopt scientific views in order to "pass the course," but still don't believe them (Linder, 1990). It would appear that there is something seriously amiss in the way in which knowledge of students' views of scientific phenomena is being used in the classroom.

Behind these attempts to incorporate knowledge of students' prior beliefs into science instruction, there appears to be lurking certain aspects of the traditional view of teaching as knowledge transmission. Such a view tends to see knowledge as a commodity that is transmitted from teacher to learner. From such a perspective, successful teaching involves the acquisition of the teacher's knowledge unchanged by the student. There are accepted scientific concepts and the teacher's job is to insure that students acquire them. (The emphasis is on the beliefs that students hold rather than on the manner in which they hold them.) The use of the term student's misconception, in particular, reflects a transmission rather than a constructivist view of teaching. In apparent recognition of this incongruence, some researchers have proposed alternative terminology--e.g., alternative frameworks (Driver & Easley, 1978), prior conceptions (Posner, 1982), children's science (Osborne & Freyberg, 1985). Recent attempts have been made to sort out some of the resulting complexity by elucidating the manner in which different terms are related to different views about the nature of concepts (Gilbert & Watts, 1983), and different views about the nature of science (Abimbola, 1988). What has been missing, however, has been any attempt to articulate how students' prior beliefs can be incorporated into a view of teaching that holds central the concept of knowledge as justified, true belief (Geddis, 1986). Any such attempt needs to focus more attention on the origin and justification of scientific knowledge and less on its inculcation.

In this paper, I argue that among science educators there has been an undue emphasis on changing students' views into those views accepted by the scientific community. This overemphasis mirrors the preoccupation with transmitting the "right answer" found in many classrooms (Geddis, 1990), and has the same tendency to deflect attention away from the origin and justification of scientific views. Ironically, it is precisely such knowledge about science that is central to curricular emphases--e.g., Science, Technology and Society--designed to help students become socially responsible citizens (Roberts, 1982). As Aikenhead (1986) points out,

> citizens exercise social responsibility partly by making critical decisions on science related issues of human affairs and social progress, and partly by acting on these decisions. . . . Generally speaking, a minimal role is played by scientific content [in such decisions], while a more crucial role is played by the individual's impressions of scientists and of the character and limits of the scientific enterprise, and also by the individual's social cognition (values, conventions, and personal orientations). (p. 130)

Given the central importance of knowledge about the origin and justification of scientific ideas to the education of responsible citizens (as opposed to the training prospective scientists), it would seem critical that the research community direct attention to articulating how <u>knowledge about science</u> (Duschl, 1990) might be communicated within the classroom. This shift in emphasis, from changing students concepts to enabling students to understand the origin and justification of scientific views, is a subtle but important paradigm shift. Such a shift in attention is congruent with the central role that <u>knowledge about science</u>, as opposed to <u>scientific knowledge</u>, plays in science education for responsible citizenship. At the same time, it has potential for coming to grips with the more global concern of science educators that students are developing erroneous conceptions of the nature of science and how it functions (Duschl, 1988; Olson & Russell, 1984; Schwab, 1962) by dealing explicitly with the origin and justification of scientific views of the world. Such a paradigm shift does not make the issue of conceptual change disappear. Learning about science does not occur in a vacuum--in order to learn about science students have to learn science content. However by focusing attention on students' learning about the nature of the scientific enterprise and how it functions, conceptual change is seen in the context of communicating views about scientific knowledge and its appropriate use within society. Such a refocusing of the goals of science education can help avoid the excesses that arise from a preoccupation with insuring students adopt the "correct" scientific view. Constructivist orientations to teaching do not appear, on their own, to be immune from such excesses. As Driver and Bell (1986) pointed out:

> By presenting science as a set of 'right answers', we may subvert students' attempts to grapple with problems themselves and to make new experiences meaningful to them. They readily substitute external authority and rote learning for internal authority and understanding. Rather than view truth as the fit between sense impressions and the real world, for a constructivist it is the fit of our sense impressions with our conceptions: the authority for truth lies with each of us. From this perspective the teaching task involves helping students organize their own experiences successfully and in a way that makes sense for _them_. (p. 453)

More than this, however, teaching needs to make central the role of epistemology. Students need to become aware of the manner in which they and science justify beliefs, and of the similarities and differences between these epistemologies.

Making Students' Aware of Epistemology

Hills (1989) has raised the important question of the nature of the untutored beliefs that students bring to the classroom. He points out that in spite of considerable disagreement over terminology--reflecting very definite differences in perspective--most researchers have assumed that in some sense students' untutored beliefs "can best be interpreted or understood as if they were scientific--albeit in some embryonic sense" (p. 160). If this is indeed the case, it makes sense to proceed in a fairly straightforward manner to try to change these beliefs. If students are developing their ideas in a manner that is similar to the way in which scientific ideas are developed, then it is not necessary to pay a great deal of attention to the genesis and epistemology of scientific views of the world. On the other hand, if the origin and justification of scientific ideas is significantly different from the origin and justification of students' untutored ideas, then it is critical to make explicit the differences, for in a very real sense students are being asked to play a fundamentally different game than the one they have been used to playing. (In fact, they may not even be aware that there is the possibility of more than one game.)

In a most compelling article, Floden, Buchmann, and Schwille (1987) have argued that for schools to satisfy their twin goals of "promoting equality of opportunity and developing disciplinary understanding" (p. 485), teachers need to help students <u>break with their everyday experience</u>.

> For, unless students can break with their everyday experience in thought, they cannot see the extraordinary range of options for living and thinking; and unless students give up many common sense beliefs, they may find it impossible to learn disciplinary concepts that describe the world in reliable, often surprising ways. (p. 485)

In arguing for students to be encouraged to break with everyday experience, Floden et al. are not arguing for school learning to be disconnected from the everyday world the student. Rather they are arguing for the initiation of students into the more objective and refined ways of knowing provided by the academic disciplines. Such an initiation provides students with alternative ways of viewing the world, while at the same time exposing to view their own everyday ways of knowing.

> Everyday life is rich in experiences that are vivid and compelling, and appear self-evident in their meaning. All of these attributes are two-edged swords. While giving learning power, they also restrict people's scope of vision, exaggerate the reliability and importance of close-to-home experience, and make it difficult to properly understand concepts from the academic disciplines. . . . These . . . natural attitudes are deceptive because, although based on limited and particular perspectives, they do not seem interpretations, but forthright apprehensions of the real world; further probing seems pointless. People going about their lives assume that their patterns of acting and thinking are not open to question; they seem so obviously right that they become invisible.

> When these patterns are not seen, alternatives are not envisioned either, becoming instead inconceivable. (pp. 486-487)

The educational potential of learning scientific views of the world, then, is not simply in the acquisition of scientifically accepted concepts, but in becoming aware of the manner in which those concepts can enable one to see and act on the world. If this potential to become reflective about thought processes is to be realized, however, science instruction has to deal explicitly with both the origin and justification of scientific views. And, it may well be that science instruction is particulary suited to make students aware of their own thought processes. According to Vygotsky (1962),

> Scientific concepts, with their hierarchical system of interrelationships, seem to be the medium within which awareness and mastery first develop, to be transferred later to other concepts and other areas of thought. Reflective consciousness comes to the child through the portals of scientific concepts. (Cited in Floden et al., 1987, p. 493)

Gil-Perez and Carrascosa (1990) provide further insight into the character of students' common sense understandings. They found that

> [students'] alternative frameworks are associated . . . with a methodology characterized by certainty, by absence of doubts or consideration of possible alternative solutions, by quick and very confident answers based on "common sense evidence" and by the lack of consistency in the analysis of different situations. (p. 534)

These findings would appear to confirm Floden et al.'s view of the inadequacies of everyday understandings and to reinforce the necessity for making explicit the methodological and epistemological differences between it and scientific understandings.

From these chara terizations of common sense methodology, it would seem that there are three central factors involved in helping students move from their common sense methodology to a scientific one. First, students need to become sceptical about what seems evident--i.e., they need to learn to doubt commonsense evidence. Secondly, they need opportunities to imagine alternative possibilities. And thirdly, they need practice in employing some of the criteria used in science to validate their alternative ideas--scope, precision, testability, internal and external consistency. There would seem to be considerable evidence that science classrooms do not provide students with experiences of this sort. Yager and Penick (1983) found that "most science courses [in the United States] do not include a single experiment where students can identify and define a problem, pose procedures, collect and interpret results or make decisions" (cited in Gil-Perez & Carrascosa, 1990, p. 537). Very similar results were found by the Science Council of Canada in a task analysis of the laboratory work contained in 64 canadian science textbooks (Orpwood & Souque, 1984).

The first half of this paper has consisted of an argument for greater attention, within constructivist orientations to science teaching, to the origin and justification of scientific views. The final portion is a case study of the teaching of waves to high school students in an introductory physics course. This case study demonstrates how the origin and justification of the scientific concept of a wave can be focused on within a constructivist perspective of science teaching.

The behaviour of waves provides an ideal context for dealing with the differences between common sense views of phenomena and scientific views. Waves can be shown to exhibit a variety of "weird" properties. Most things slow down and stop as they travel along after been given a push. Wave pulses on a spring, however, travel at a constant speed. This speed is different in different springs. Pulses even speed up as they travel from one spring into another seemingly defying common sense. The following case study focuses on how two wave pulses behave after they have met in the middle of a spring.

Physics Ghosts--Breaking With Everyday Experience

Waves are an important topic in introductory physics because of the way in which they can be used to explain the behaviour of other phenomena such as light, sound, and matter. The behaviour of waves, however, is full of many surprises for the novice physics student. The following case study is based on an introductory lesson to waves that I have given to numerous grade 11 physics students over the last ten years.

Usually I demonstrate the behaviour of waves using a long "slinky" spring that produces slow moving pulses that can be seen easily. After some casual observation of how pulses move, I challenge students to observe carefully what happens after two pulses meet in the middle of the slinky. With the assistance of one of the students, two pulses of equal amplitude are produced travelling towards each other from opposite ends of the slinky. Students observe two similar pulses that initially move towards each other and then move apart.

Insert Figure 1 about here

When questioned as to what they have seen, the majority of students report that they have seen the waves "bounce off each other," and return to the end from which they originated. Usually there are a couple of students who suggest that the waves have "passed through each other" and continued on to the other end of the slinky. I respond to this second suggestion with a look of incredulity, and ask the student to repeat their answers as if I haven't heard them correctly. In the course of the discussion that follows, I outline on the blackboard the manner in which both the "Bounce Off" theory (BO) or the "Pass Through" theory (PT) explain what is observed--i.e., two identical pulses that first move towards each other and then move away from each other. I emphasize, however, that we are concerned with approaching this phenomena from a "scientific" viewpoint, and that the idea of things passing through each other seems more like fantasy than science to me.

At this point I remind students that one of the important characteristics of science is that it employs experiments to find out more about different phenomena. I challenge them to design an experiment that would enable them to chose between the two theories--Pass Through or Bounce Off. What inevitably follows is a most interesting discussion that focuses on the need to identify each of they waves--so that they can determine whether it passes through or bounces off--and various suggestions about how this might be accomplished[2]. A student usually suggests that one of the waves could be differentiated by making it larger. Using this suggestion, we carefully lay out on the black board the predictions that follow from each of the two theories, and then return to the slinky to observe the pulses in the slinky.

Insert Figure 2 about here

As can be seen from Figure 2, it would appear that the PT theory makes the correct prediction. "But this is ridiculous," I object. "After all, things can't really pass through other things--likes ghosts." After considerable histrionics, I suggest a modified bounce-off theory. "During the collision, energy must be being transferred from the larger pulse to the smaller one. As a result, the smaller pulse becomes larger and the larger pulse becomes smaller." I then demonstrate that the two dynamic carts behave in a similar manner when they collide--a light, slow moving cart moving off with a high speed when hit by a heavier cart. With this modified theory--"Bounce Off Plus Energy Transfer" (BO+ET)--we am able to explain the observed behaviour of the large and small pulse after they meet in the centre of the spring.

Again I challenge students to design an experiment that can help show which of the two theories is really better. After a while, someone usually suggest that we make one of the pulses a crest and the other a trough. With this strategy for identifying the two pulses, we then outline on the black board what each of the two theories would predict before returning to the slinky to investigate the phenomena directly.

Insert Figure 3 about here

Once again it appears as if PT has been able to correctly predict what we observe! But again I object, that I can't really take seriously this idea of pulses passing through each other as if they were ghosts. Returning to the spring, I demonstrate how when one end of the slinky is held fixed that a crest is reflected from that fixed end as a trough. "There!" I exclaim, "All I have to do is modify my theory to take account of this. What is really happening is that the pulses are transferring energy, and flipping over, when they bounce off each other (BO+ET+FO)." So once again, we've been able to produce a bounce off theory that is able to explain the observations.

What happens next depends very much on the group of students. Frequently, after a short pause, one student will observe that my modified theory is now in trouble with what we observed in the first experiment. If I am to claim that waves "flip over" when they bounce off each other, then our first experiment should have resulted in two troughs retreating from each other. In fact, it yielded two crests.

Insert Figure 4 about here

At this point, we engage in a discussion of some of the characteristics of science that this activity had demonstrated. The importance of what the pulses were observed to do is of course central. However, these observations are influenced by our theories about what is going on. Our everyday experience leads us to believe that pulses should "bounce off" each other in the same way that billiard balls, and football players do. Because of this we literally "see" the two similar pulses in the first experiment bounce off each other. It is only when we question this obvious evidence, that we begin to accumulate evidence that eventually leads us to adopt the most uncommon sense view that these pulses actually pass through each other. In order to proceed to the second and third experiments, we have to first see that both the Pass Through and Bounce Off theories explain the observations from the first experiment. Then we have to realize that it is necessary to be able to distinguish between the two pulses in order to design an experiment that will enable us to chose between the two theories. Accompanying all of this is the underlying message that people (scientists included) do not give up their ideas easily. Certainly there is no necessary conviction that our theory will initially be correct in all respects. As a result, we may introduce modifications and additions in order to help increase its scope[3]. (In retrospect, of course, these actions can be seen as a desperate attempt to avoid having to change our central convictions.) It is only when we have some major crisis--like the lack of internal consistency of the (BO+ET+FO) theory--that we may give up on our favourite theories.

Conclusion

In this paper, I've argued that science educators concerned with the untutored views of scientific phenomena held by students need to focus more attention on articulating how classroom instruction can promote student understanding of the origin and justification of scientific ideas. Instruction _about science_ deserves particular attention in science education programs aimed at producing socially responsible citizens. Understanding of the nature and limits of scientific knowledge is of critical importance in any attempts to employ science in personal or societal decision making--as proposed by science curricula that employ a Science-Technology-Society emphasis. Just as important, teaching which aims at the scientific education, as opposed to training, of students presupposes attention to the epistemology of knowledge claims. To date, many science educators concerned with promoting constructivist views of teaching, have focused on the problem of changing students' misconceptions. There is little doubt that this work is of considerable importance. In the process, however, it is important not to lose sight of the centrality to education of the manner in which beliefs--scientific and every day--are held.

Footnotes

[1] The use of the term in this context may be seen as somewhat pretentious. Obviously I do not mean anything as grand as, for example, the Kinetic Molecular Theory of Gases. Here, all that is meant is that the idea of two things bouncing off each other on impact, can be used to explain and predict the behaviour of the wave pulses.

[2] The design of experiments is a demanding task that often involves both creativity and a certain amount of "mucking about". Drawing on their previous experience, students will sometimes propose identifying a pulse by attaching some masking tape to the slinky. Usually it is necessary to actually try this out before students grasp that, in this case, it is not a viable strategy.

[3] This can be seen to reflect the manner in which Lakatos (1970) proposes that progressive research programs within science invent "auxiliary hypothesis" which function as a protective belt around their hard core. "It is this protective belt of auxiliary hypotheses which has to bear the brunt of [experimental] tests and get adjusted and re-adjusted, or even completely replaced to defend the thus-hardened core (p. 133).

References

Abimbola, I. O. (1988). The problem of terminology in the study of student conceptions in science. Science Education, 72(2), 175-184.

Aikenhead, G. S. (1986). Science curricula and preparation for social responsibility. In R. W. Bybee (Ed.), NSTA Yearbook: Science Technology Society (pp. 129-142). Washington, DC: NSTA.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990). Applying the "cognitive conflict" strategy for conceptual change--Some implications, difficulties, and problems. Science Education, 74(5), 555-569.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. Studies in Science Education, 5, 61-84.

Driver, R., & Bell, B. (1986). Students' thinking and the learning of science: A constructivist view. School Science Review, 67, 443-456.

Duschl, R. A. (1988). Abandoning the scientistic legacy of science education. Science Education, 72(1), 51-62.

Duschl, R. A. (1990). Teaching of theory: A guiding concept in science education. Commissioned Paper to BSCS/SSEC for NSF Grant Project "History and Philosophy of Science & Technology."

Eylon, B., & Linn, M. C. (1988). Learning and instruction: An examination of four research perspectives in science education. Review of Educational Research, 58(3), 251-301.

Floden, R. E., Buchmann, M., & Schwille, J. R. (1987). Breaking with everyday experience. Teachers College Record, 88, 485-506.

Geddis, A. N. (1986). Perspectives on Knowledge in the Classroom: A Case Study in Science Teaching (Doctoral dissertation, University of Toronto, 1985). Dissertation Abstracts International, 47, 1589A.

Geddis, A. N. (1990). The tyranny of the "right answer": The systematic distortion of scientific knowledge. Paper presented at the annual meeting of the Canadian Society for the Study of Education, Victoria BC.

Gilbert, J. K., & Watts. D. M. (1983). Conceptions, misconceptions and alternative conceptions: Changing perspectives in science education. Studies in Science Education, 10, 61-98.

Gil-Perez, D., & Carrascosa, J. (1990). What to do about science "misconceptions." Science Education, 74(5), 531-540.

Hewson, P. W. (1985). Epistemological commitments in the learning of science: Examples from dynamics. European Journal of Science Education, 7(2), 163-172.

Hills, G. L. C. (1989). Students' "untutored" beliefs about natural phenomena: Primitive science or commonsense? Science Education, 73(2), 155-186.

Hodson, D. (1988). Towards a philosophically more valid science curriculum. Science Education, 72(1), 19-40.

Lakatos, I. (1970). Falsification and the methodology of scientific research programmes. In I. Lakatos & A. Musgrave (Eds.), Criticism and the Growth of Knowledge (pp. 91-196). London: Cambridge University Press.

Linder, C. J. (1990). Is conceptual change something science teachers should be striving for? Paper presented at the annual meeting of the Canadian Society for the Study of Education, Victoria BC.

Linn, M. C. (1983). Content, context, and process in adolescent reasoning. Journal of Early Adolescence, 3, 63-82.

Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Towards a principled teaching strategy. Instructional Science, 11, 183-200.

Olson, J., & Russell, T. (1984). Science Education in Canadian Schools: Volume III Case Studies of Science Teaching. Ottawa ON: Science Council of Canada.

Orpwood, G. W. F., & Souque, J. (1984). Science Education in Canadian Schools: Volume I Introduction and Curriculum Analyses. Ottawa ON: Science Council of Canada.

Osborne, R., & Freyberg, P. (Eds.), Learning in science: The implications of children's science. Auckland, New Zealand: Heinemann.

Posner, G. J. (1982). Cognitive science and a conceptual change epistemology: A new approach to curricular research. The Journal of Curriculum Theorizing, 4 1), 106-126.

P sner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. Science Education, 66(2), 211-227.

Roberts, D. A. (1982). Developing the concept of "curriculum emphases". Science Education, 66(2), 243-260.

Rowell, J. A., Dawson, C. J., & Lyndon, H. (1990). Changing misconceptions: A challenge to science educators. International Journal of Science Education, 12(2), 167-175.

Schwab, J. J. (1962). The teaching of science as enquiry. In J. J. Schwab & P. F. Brandwein (Eds.), The teaching of science (pp. 1-103). Cambridge MA: Harvard University Press.

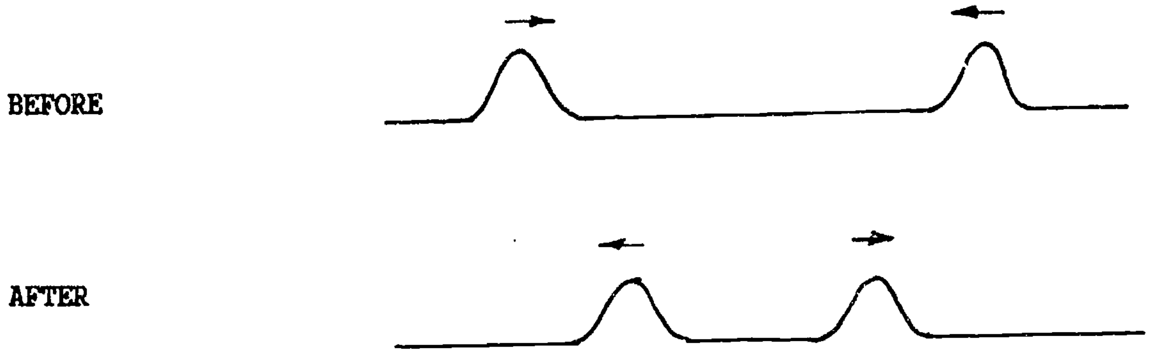

Figure 1. Two Identical Wave Pulses on a Slinky Spring

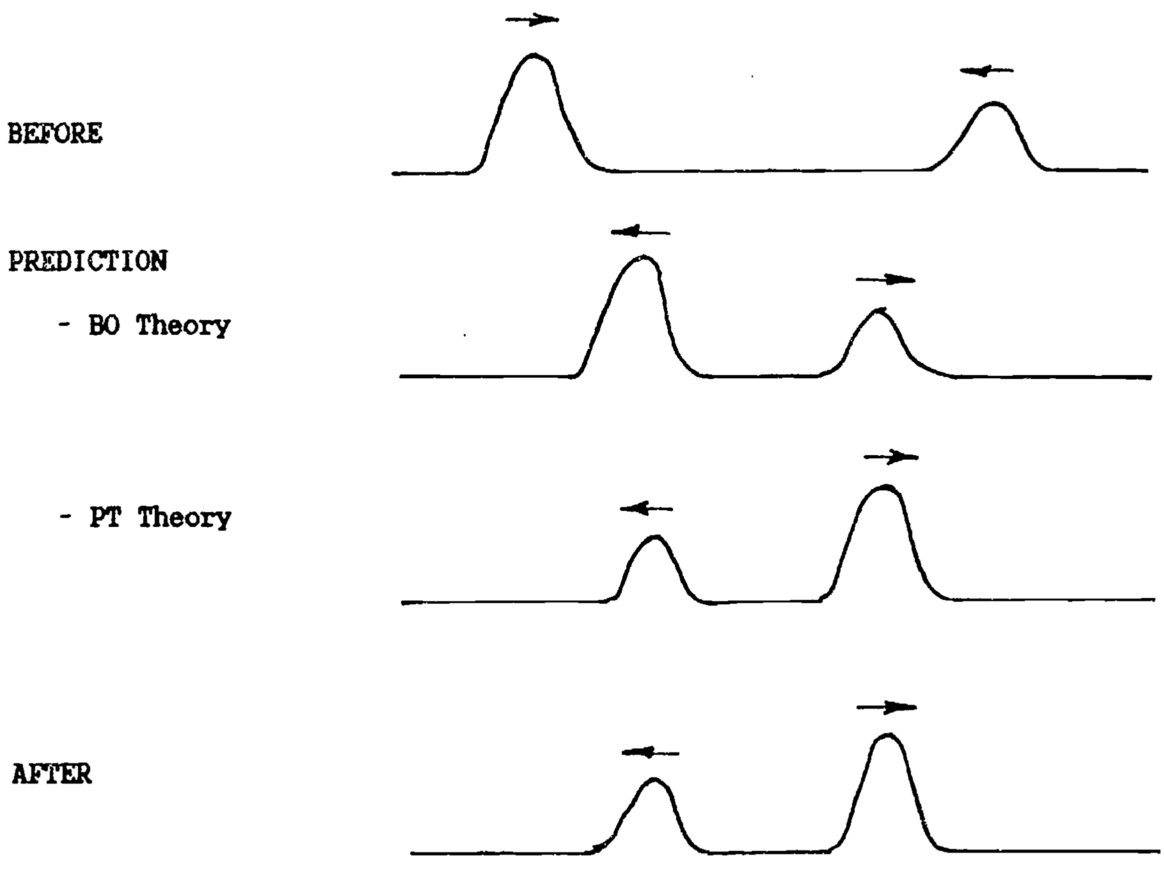

Figure 2. Two Wave Pulses with Different Amplitudes

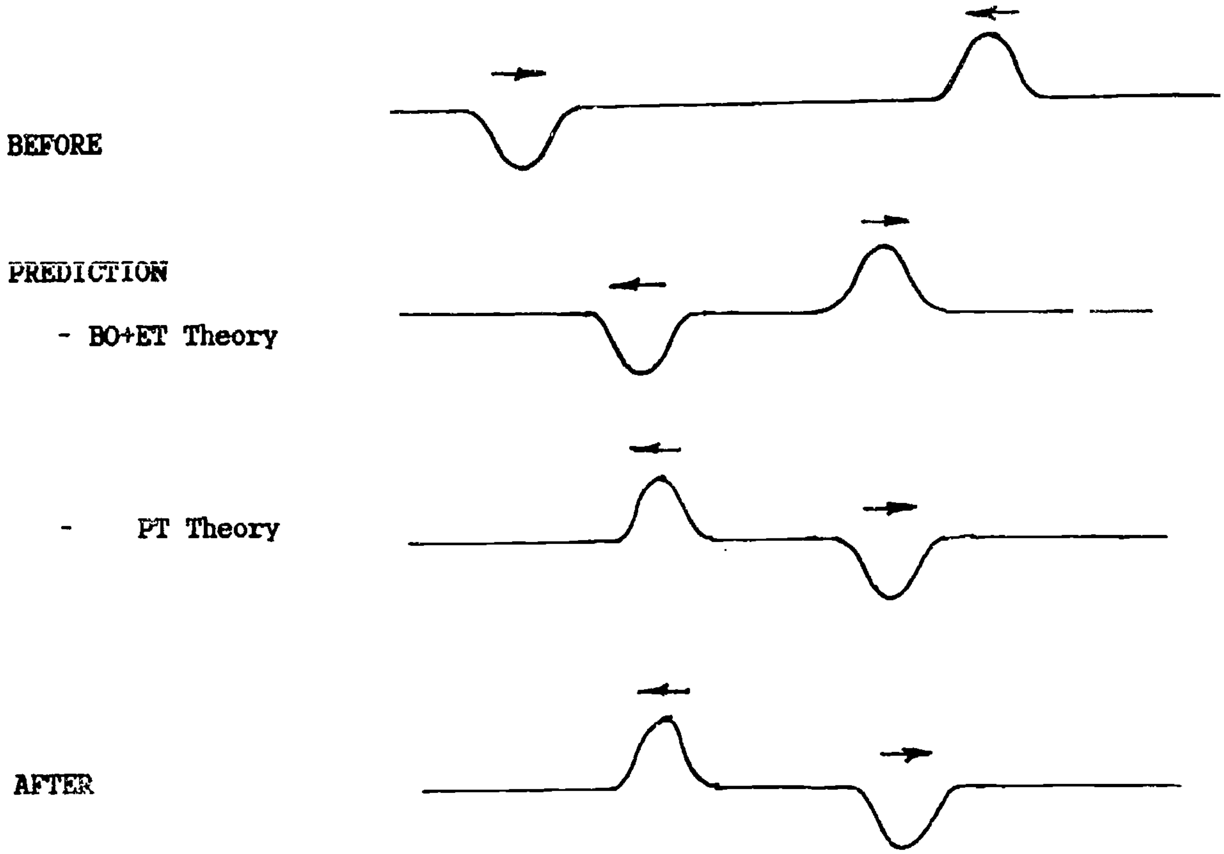

Figure 3. Two Wave Pulses with Opposite Phase

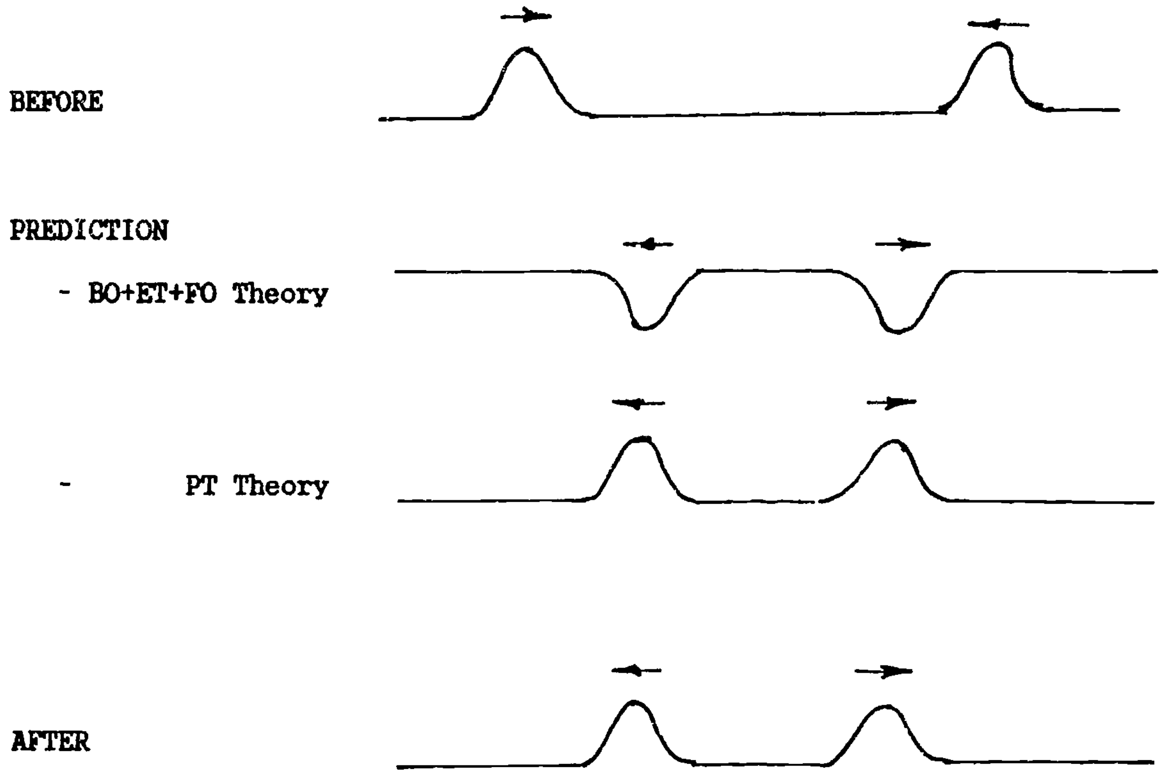

Figure 4. Two Identical Wave Pulses